MPPT Based on Neural Networks for Solar PV Systemswith Real time Irradiance Levels

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Abstract: ***Solar energy is one of the prominent formsof renewable energy sources that can be used toreplace the requirement of fossil fuels up to a certain extent. To harvest solar energy, a photovoltaic (PV) with higher efficiency is required. In order to achieve this higher efficiency of solar PV, it is required to trace the maximum power point (MPP) with a simultaneous change in irradiation and temperature. This article focuses on the achievementof MPP tracking of solar PV through a neural network-based intelligent technique which provides a more accurate and efficient response than conventional techniques like IC (incremental conductance) technique. Mathematical modeling of solar PV is also included in this article.***

Keywords: MPPT, Photovoltaic, Neural network, PV modeling, incremental conductance.

1. Introduction

Much of the world's energy is now derived from fossil fuels. Consumption of these sources results in greenhouse gas emissions, as well as an increase in pollutants [1]. Furthermore, excessive usage of natural resource reserves diminishes this form of energy in a way that is detrimental for future generations. Renewable energy sources such as solar unlike fossil fuels, are limitless and minimize greenhouse gas emissions. Renewable energies are divided into several technology clusters based on the source of energy valued and the amount of useful energy obtained. A solar generator, a DC-DC converter, and a load make up the photovoltaic structure employing solar energy. The effectiveness of the system increases after the maximum power point tracking technique is used, regardless of the irradiance or temperature of thesurroundings.

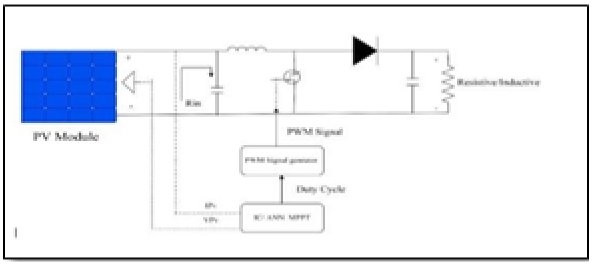

Figure 1: General block diagram of a solar photovoltaic system

Several articles use fuzzy logic, neural networks, or particle swarm optimization to solve the challenge of finding the best maximum power point tracking [12]. Machine learning has become increasingly popular in recent years thanks to the development of Artificial Intelligence (AI). This method yields the most precise results in the shortest amount of time. Other MPPT algorithms cannot match the efficiency provided by the neural network MPPT [11]. In the first section of this article, the modeling of the PV module was developed in MATLAB & results were compared with the actual PV module. In the second section, the artificial neural network was presented & trained using the LM (Levenberg Marquardt) and the backpropagation approach to trace the maximum power of the same PV module and the results are compared with a conventional method.

2. Mathematical Modeling of PV Module

A single diode circuit model is used to hypothetically simulate a PV module. Internal characteristics include ideality constant, Boltzmann constant, bandgap, and electron charge, whereas open-circuit voltage (Voc), short-circuit current (Isc), series resistance, and shunt resistance are all examples of electrical characteristics [2].

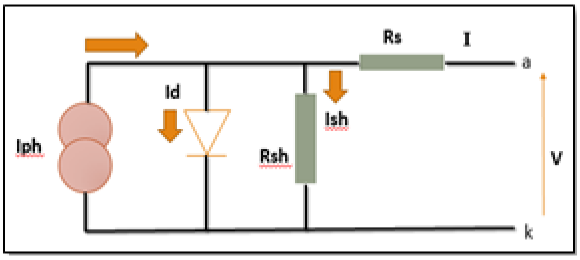

Figure 2: Single diode ckt. Diagram

Iph: Photon current in Single diode ckt (A)
Io: Diode saturation current in Single diode ckt (A)
Q: Electron charge-1.6×10-19 (C)
T: Operating temperature in Kelvins
A: Ideality factor-1.2 [4]

For the simulation, a PV module rated at 60W is used asa reference. The current generated by the panel can be presented by:

$$I = I_{ph} - I_0\left(\exp\frac{q(V+R_S I)}{aKTN_s} - 1\right) - \frac{(V+R_S I)}{R_{sh}}$$

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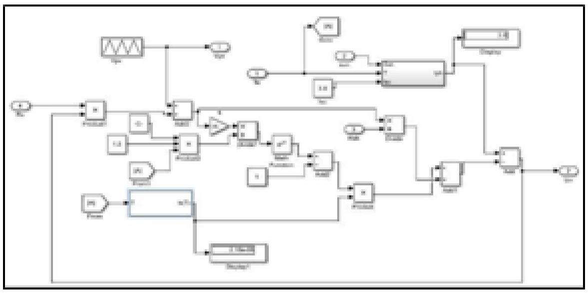

Figure 3: Current by panel

Also diode saturation current is given by:

$$I_s(T) = I_s \left(\frac{T}{T_e}\right)^3 * e^{\left[\left(\frac{T}{Te}-1\right)*\frac{Eg}{N*Vt}\right]}$$

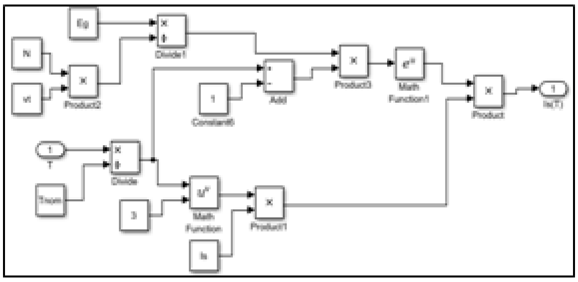

Figure 4: Diode saturation current

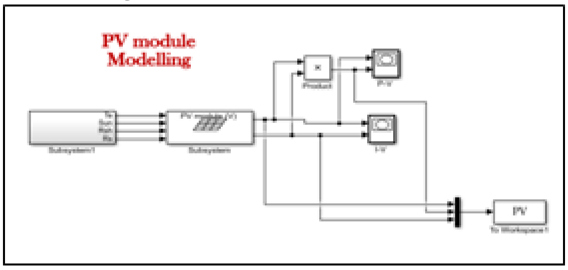

Figure 5: PV module main circuit

This module consists of the main module's inputs, which are the temperature of 25 degrees, the irradiation level of 1000w/m^2, and the shunt and series resistances set to 1000ohm & 0.008ohm, respectively, and the PV module, where we modelled our equations, which are then connected to the PV and IV graphs, where we can see the maximum power as well as other parameters.

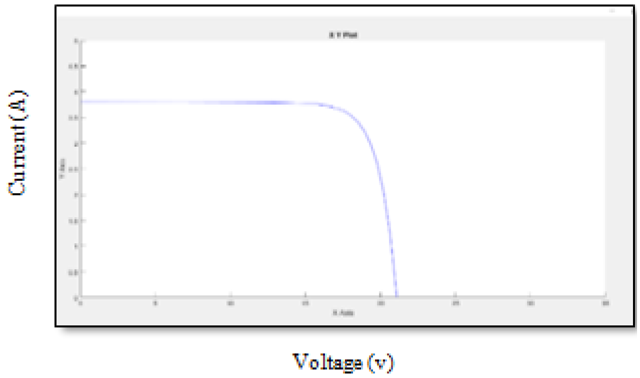

Figure 6: IV curve of module

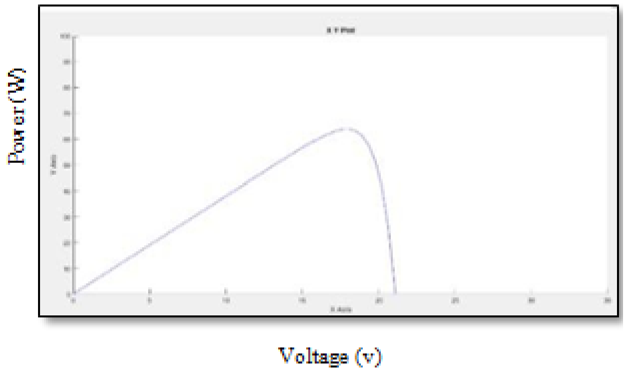

Figure 7: PV curve of module

After the modelling, the specified power of 60W was obtained as shown in the PV curve means the obtained model is matching with the manufacturer'sspecifications.

The module's operating temperature is influenced by factors such as the encapsulating material, heat dissipation and absorption properties, the module's working point, ambient parameters, and unique installation conditions. [3].

3. Classical Incremental MPPT

The MPP voltage, which is dependent on the incrementally plus instantaneous conductance of the modules, is used to modify the array terminal voltage inthe IC method.

The voltage must be increased on the left side of MPP to achieve MPP, and it must be decreased on the right side to reach MPP.

This method's basic equations are [5]:

$$\frac{dP}{dV} = 0;\ \text{MPP (slope)} \ldots\ldots (1)$$

$$\frac{dP}{dV} > 0;\ \text{left sides of MPP} \ldots\ldots (2)$$

$$\frac{dP}{dV} < 0;\ \text{right sides of MPP} \ldots\ldots (3)$$

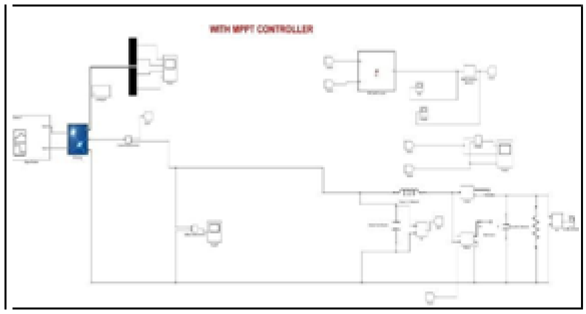

Figure 8: Simulation circuit of PV system with IC MPPT controller for variable irradiation & temperature

Here with the same variable inputs, we have implemented the circuit along with the conventional algorithm which is IC-based. In that algorithm voltage & current levels from the panel is given as an input to itwhere this algorithm produces the required change in duty cycle in order to reach the MPP

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which is further given to PWM generator which provides the necessary gate pulses for triggering the MOSFET switch of the boost converter.

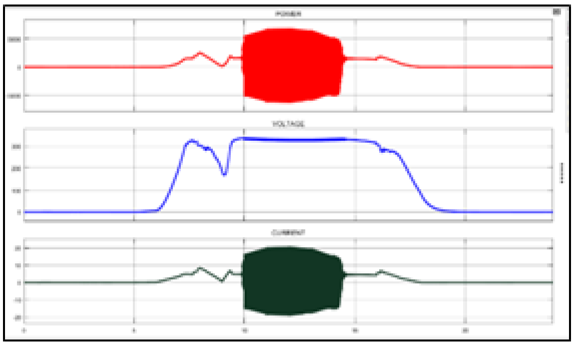

Figure 9: Final obtained power for variable irradiation and temperature with MPPT

This is the curves for output parameters. The inputpower for this ckt. Is 230.6W and the tracked power is 148.26W. So, the power difference is 82.4W whereas without implementing any MPPT controller the power tracked difference is 98W.

4. Intelligent Neural Network MPPT

Artificial intelligence (AI) provides a number of advantages over traditional methods. Traditional methods have the problem of being sluggish to respond to unexpected changes in solar temperature or irradiance conditions, and they sometimes fail to trackthe highest power point [6].

The following are the steps for creating an ANN:

- Data collecting
- Network structure selection
- Network training

The input variables for ANN [7] are temperature and irradiance, while the output variable is voltage at MPP. To train the neural network, some data must be obtained as inputs and output.

Training - In this work, the backpropagation ANN composed of three hidden layers is used with tansig activation functions.

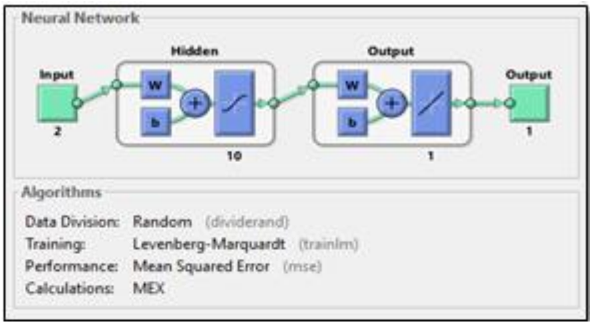

Figure 10: Training plot of neural network

We trained the neural network using 1 day of virtual real time data collected from NASA access website using LM approach. This is widely used to solve nonlinear optimization problems, such as the nonlinear inputs in our case. [8] After training, the controller wasimplemented in our main circuit, and the power tracked difference we are getting is only 48W, demonstrating the accuracy of AI over conventional techniques.

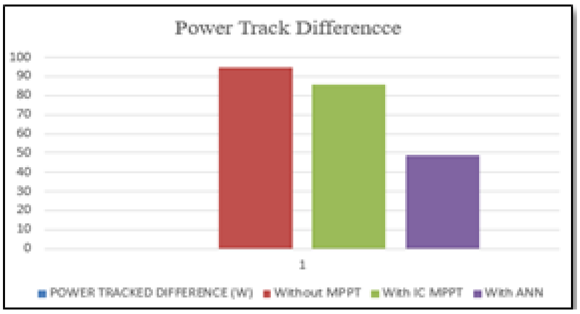

Figure 11: Comparison chart

We have now extended our input data to two months, with a total sample size of 1464, of which 220 are being used for training and 220 have been used for testing. Forthat case the obtained MSE is 1e-07 shown below and the plot for error histogram has been shown.

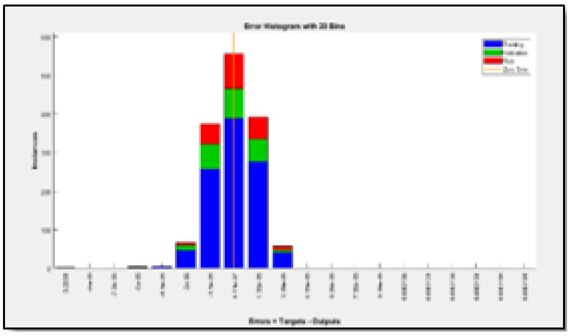

Figure 12: Error histogram plot

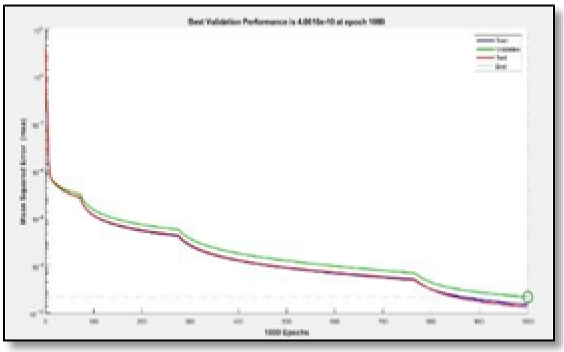

Figure 13: Mean square error

The finest training functions for PV MPPT controller is determined through performance evaluation [9]. At the completion of training, a well-trained artificial neural network (ANN) willhave a very low mean squared error.

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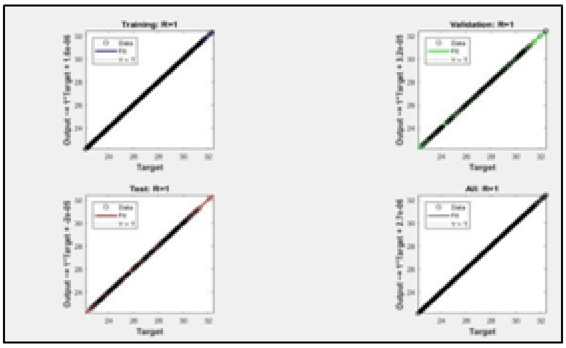

Figure 14: Regression plot

The regression plot above with R=1 shows the precisionof our given data with trained data.

For Resistive Load

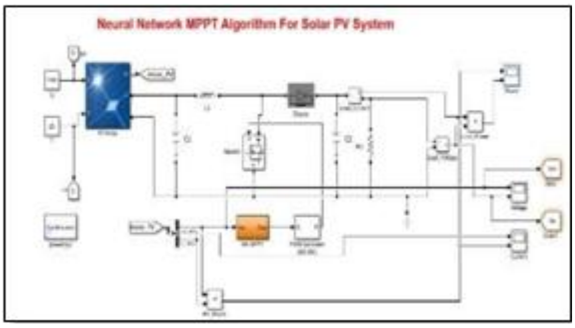

Figure 15: Neural network (NN) MPPT ckt with resistive load forconstant inputs

This is the equivalent ckt for neural network-basedMPPT for a solar PV system with two inputs, irradiation and temperature, connected to a panel with a resistive load.

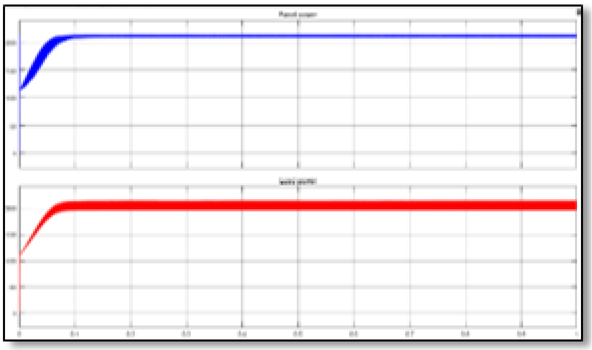

Figure 16: Panel power and tracked power

Here, the panel power is 208.8W, and the load power is 202.1W as shown below.

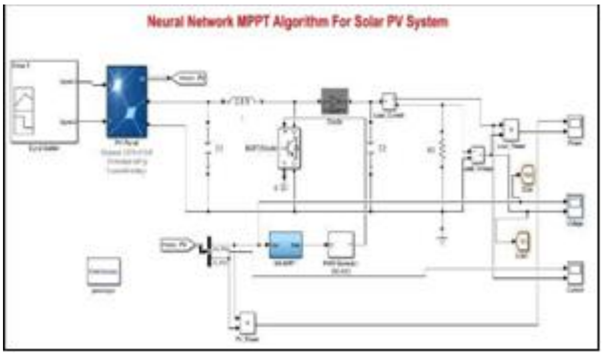

Figure 17: Neural network based MPPT ckt with resistive load for variable inputs

Now we have varied the irradiation and temperature conditions in this case. So, the panel power is 131.7W and the load power is 127.1W.

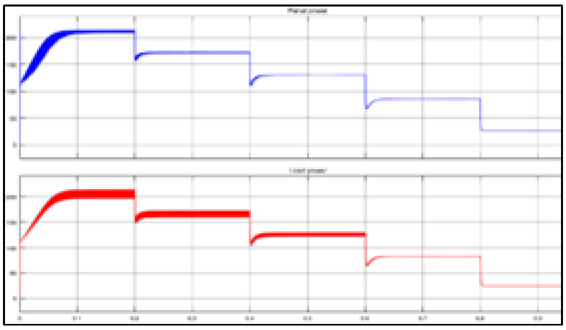

Figure 18: Panel power and tracked power

For Inductive Load

We also have considered another load which is inductivetype where we have taken an asynchronous Machine connected by self-designed inverter with 180-degreeconduction mode.

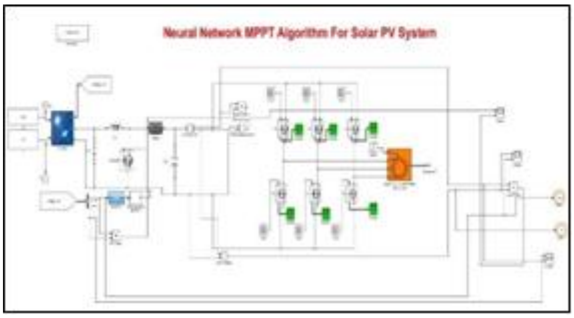

Figure 19: With NN MPPT controller with inductive load for constant irradiation (G) & temperature (T)

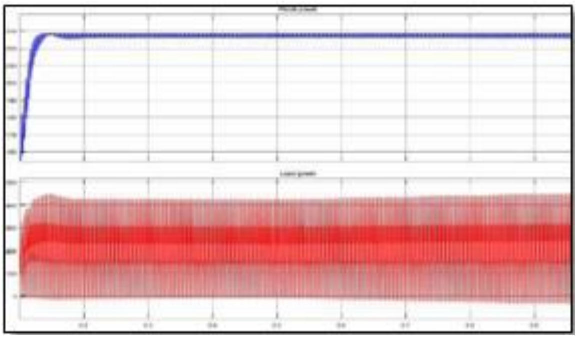

Figure 20: Panel power and tracked power for constant irradiation (G) & temperature (T)

Without implementing any MPPT controller, the panel power is 114.4W & tracked load power is 90.3W whilewith NN-based MPPT, the panel power is 220.8W & tracked load power is 210.8W for constant irradiation & temperature.

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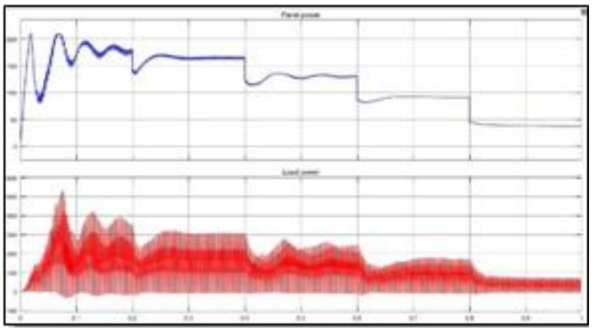

Figure 21: Panel power and tracked power for variable irradiation (G) & temperature (T)

For varying irradiation & temperature levels the panel power is 231.2W while tracked load power is 222.3W.

Table 1: Comparison without MPPT and with IC, NN MPPT

S. No.	Cases	Power Tracked Difference	
		Resistive Load	Inductive Load
1.	Without MPPT	98W	25W
2.	With IC MPPT	82W	15.5W
3.	With ANN MPPT (Constant G & T)	6W	11W
4.	With ANN MPPT (Variable G &T)	4.5W	9W

5. Conclusion

This paper highlighted the mathematical modeling of PV module which provides a strong understanding of the behavior with analyzing the parameters involved & particularly the I-V, P-V characteristics. Also, by employing neural network-based MPPT, more precise results in the tracking of power were obtained as with neural network the power difference between input & load power is only around 4.5W-11W for all the cases with resistive or inductive loads, unlike IC MPPT where power difference was around 82W with resistive load & 15.5W with inductive load. The development of a neural network MPPT method on hardware could be a future project.

References

[1] Abdessamia Elgharbi1, Dhafer Mezghani 1, Abdelkader Mami2," A Maximum Power Point Tracking Method Based on Artificial Neural Network For A PV System" in International Journal of Advances in Engineering & Technology, Nov. 2012, ISSN: 2231-1963.

[2] Savitha p b, Shashikala m s, Puttabuddhi k l, "Modelling of 250wp photovoltaic module and its performance analysis using matlab /simulink "in International Journal of Electrical, Electronics and Data Communication", Volume-2, Issue-7, July- 2014.

[3] Rokeya Jahan, Mukti and Ariful Islam. "Modeling and Performance Analysis of PV Module with Maximum Power Point Tracking in Matlab/Simulink "in Applied Solar Energy, Vol. 51, No. 4, October 2015, doi: 10.3103/S0003701X15040155.

[4] K. Bilhan, A. Caliskan and S. Unal, "Simulation of a photovoltaic panels by using Matlab/Simulink," *2016 8th International Conference on Electronics, Computers and Artificial Intelligence (ECAI)*, 2016, doi: 10.1109/ECAI.2016.7861124.

[5] Banu and M. Istrate, "Modeling of maximum power point tracking algorithm for photovoltaic systems," *2012 International Conference and Exposition on Electrical and Power Engineering*, 2012, doi: 10.1109/ICEPE.2012.6463577.

[6] L. P. N. Jyothy and M. R. Sindhu, "An Artificial Neural Network based MPPT Algorithm for Solar PV System," 2018 4th International Conference on Electrical Energy Systems (ICEES), 2018, pp. 375-380, doi: 10.1109/ICEES.2018.8443277.

[7] Farzad Sedaghati, Ali Nahavandi, Mohammad Ali Badamchizadeh, Sehraneh Ghaemi, Mehdi Abedinpour Fallah, "PV Maximum Power-Point Tracking by Using Artificial Neural Network", Mathematical Problems in Engineering, vol. 2012.

[8] Bataineh and D. Kaur, "A Comparative Study of Different Curve Fitting Algorithms in Artificial Neural Network using Housing Dataset," *NAECON 2018 - IEEE National Aerospace and Electronics Conference*, 2018, pp. 174-178.

[9] Ruchira, Patel R.N., Sinha S.K. (2019)," Comparison of ANN-Based MPPT Controller and Incremental Conductance for Photovoltaic System" In: Nath V., Mandal J. (eds) Proceeding of the Second International Conference on Microelectronics, Computing & Communication Systems (MCCS 2017). Lecture Notes in Electrical Engineering, vol 476. Springer, Singapore.

[10] H. H. Lee, L. M. Phuong, P. Q. Dzung, N. T. Dan Vu and L. D. Khoa, "The new maximum power point tracking algorithm using ANN-based solar PVsystems," *TENCON 2010 - 2010 IEEE Region 10 Conference*,2010,doi:10.1109/TENCON.2010.568 6721.

[11] Sharmin, Ruhi & Chowdhury, Sayeed & Abedin, Farihal & Rahman, Kazi. (2021). "Implementation of MPPT Technique of Solar Module with Supervised Machine Learning".

[12] K. Y. Yap, C. R. Sarimuthu and J. M. -Y. Lim, "Artificial Intelligence Based MPPT Techniques for Solar Power System: A review," in *Journal of Modern Power Systems and Clean Energy*, vol. 8, no. 6, pp. 1043-1059, November 2020, doi: 10.35833/MPCE.2020.000159.

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